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ABSTRACT

This teacher's guide presents teaching suggestions and presentation materials about how daily human activities, such as energy use, add pollutants to the atmosphere. The lesson is divided into seven parts and can be taught in two or more class periods. Student handouts include: (1) "Total Energy Use by Fuel Type, 1991"; (2) "Facts about Air Pollution"; (3) "Facts about Global Warming and Ozone Depletion"; and (4) "Reducing Carbon Emissions." Transparency masters are titled: (1) "Trends in Global Energy Consumption"; (2) "How the Greenhouse Effect Works"; (3) "Contributions to Global Warming"; (4) "Global Fossil Fuel Consumption, 1950-90"; (5) "Atmospheric CO2 Concentrations, 1860-1990"; (6) "The Greenhouse Index: 10 Countries with the Highest Greenhouse Gas Emissions, 1991"; (7) "Stratospheric Ozone Depletion, 1979-1991"; (8) "Number of Vehicles in the World"; and (9) "Energy Intensities in Developed Countries." (EH)

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TEACHER'S GUIDE

To World Resources

Energy, Atmosphere, and Climate

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to

World Resources:

Energy, Atmosphere, and Climate

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Teacher's Guide to World Resources:

Energy, Atmosphere, and Climate

Comprehensive Coursework on the Global Environment

About the World Resources Institute

The World Resources Institute (WRI) is a research and policy institute helping governments, the private sector, environmental and development organizations, and others address a fundamental question: How can societies meet human needs and nurture economic growth while preserving the natural resources and environmental integrity that make prosperity possible?

Through its policy studies, WRI aims to generate accurate information about global resources and environmental conditions, analyze emerging issues, and develop creative yet workable policy responses. In seeking to deepen public understanding, it publishes a variety of books, reports, and papers; undertakes briefings, seminars, and conferences; and offers material for use in educational settings and in the news media.

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Using World Resources Teacher's Guide Units

World Resources *Teacher's Guide* Units are designed for use at the secondary school level (although we have reports of successful use at the middle school and college levels). They weave together lessons about both environment and development, both globally and locally. They draw on skills and knowledge from the physical and biological sciences, social studies, history, economics, civics, and global studies.

Information and analysis used in the Units are drawn from World Resources Institute (WRI) publications and databases. All units are written by curricula writers and reviewed by educators as well as by technical experts. The Units are updated and revised periodically based on feedback from classroom teachers who have used the materials.

Our intent is to provide easy-to-use, inexpensive classroom materials that contain the most recent and authoritative information on the global environment because we believe it is crucial that the next generation of leaders and citizens understand the issues described here.

The complete set of *Teacher's Guide* Units includes the following topics:

- Biodiversity
- Car Trouble
- Citizen Action
- Energy, Atmosphere, and Climate
- Natural Resource Economics
- Oceans and Coasts
- Population, Poverty, and Land Degradation
- Sustainable Development
- Two Giants: China and India
- Watershed Pollution
- Women, Equity, and Sustainable Development

These units have been revised and updated with the most recent data available as of spring 1994.

Inside Each Unit

Each *Teacher's Guide* Unit should contain enough teaching suggestions and presentation materials to teach one to several classes on the topic without securing additional resources. On the other hand, each unit is designed to point teachers and students to additional resources and to offer suggestions for expanded coursework. Specifically, each unit contains objectives, a lesson plan, student handouts, overhead transparency masters, student enrichment activities, suggestions for further reading, and suggested audiovisual resources.

Using the Units for Environmental Studies

The *Teacher's Guide* Units provide a comprehensive, consistent yet highly flexible set of materials for environmental studies courses. They can be used in conjunction with an environmental science textbook to give students an understanding of basic environmental systems and cycles. Or they can be used in a social studies context to examine some of the tough problems and choices we face as a society.

Educators who want to go beyond the *Teacher's Guide* Units can read related WRI publications, which provide the basic data, source materials, and analysis for the Units. These publications are listed at the beginning of each unit. A free catalog can be obtained by calling 1-800-822-0504.

Integrating Teacher's Guide Units into the Curriculum

Secondary school teachers frequently mention the difficulty of integrating environmental issues into a tightly packed curriculum. As much as they would like to teach about the environment, they must devote class time to required subjects.

To help them place these issues in their curricula, we have coded each lesson plan and each student enrichment activity to the draft national performance assessment standards for science, math, history, civics, and geography. These standards are being developed as part of the national Goals 2000 program in the U.S. Department of Education. The standards themselves are being developed, discussed, and revised by educational organizations in nine academic disciplines. They are expected to be approved at the national level, then offered to states to incorporate into their own academic assessment plans. Although this process will take several years, we have compiled lists of assessment standards for grades 9 through 12 from drafts available in spring 1994 to offer some guidance to teachers.

A complete list of the draft standards for Grades 9 through 12 appears in Appendix B, which should be mailed to you with your order. Appendix A provides a bibliography and list of related organizations.

Integrating Global Environmental Education into High School Curricula

In an effort to link lessons about global environment and development issues to required school curricula, we have identified which parts of the lesson plan and which student enrichment activities in this *Teacher's Guide* Unit relate to the draft national performance standards developed recently for civics, geography, history, math, and science in grades 9 through 12.

These voluntary national standards are part of the Goals 2000 program mandated by the Goals 2000: Educate America Act of 1994 under the direction of the U.S. Department of Education. Among other things, Goals 2000 will establish a set of goals or performance standards for grades 4, 8, and 12 in the subjects listed above plus English, the arts, and foreign languages. These goals will be available to the states for incorporation into their own sets of educational performance standards. Each set of draft standards was developed by a professional education organization and has been presented at numerous educational conferences for review and comment. The draft standards used here are those available as of spring 1994.

Although many countries have national performance standards, the United States (and Canada) have treasured a decentralized educational system that sets education goals at the district or state level. Goals 2000 is the first attempt to identify a set of general education objectives that all students in the country are expected to achieve. As might be expected, there is some controversy over whether there should be national education goals—even voluntary ones—and if so, what they should be.

Regardless of the final outcome, we feel the draft goals do reflect some consensus among educators about what material should be covered at various grade levels, and as such, offer some guidance for integrating environmental education into the curricula.

Only those goals relevant to this unit are listed here. A complete list of goals appears in the 1994 *Teacher's Guide to World Resources*. Copies of reports outlining the goals for each subject area can be obtained from the education organizations listed at the top of each set of goals on this page. Information about the Goals 2000 program is available at 1-800-USA-LEARN.

Goals 2000: Draft National Performance Standards

Civics and Government*

(Draft National Standards, October 1993, Center for Civic Education, 5146 Douglas Fir Road, Calabasas, CA 91302-1467)

	Lesson Plan	Enrichment Activity
IV. What is the Relationship of American Politics and Government to World Affairs?		
1. How is the world organized politically?		1
3. How has the United States influenced other nations and how have they influenced American politics and society?	9	1
V. What are the Roles of the Citizen in the American Political System?		
4. How can citizens participate in public life?		7

Geography*

(Draft National Standards, October 1993, National Council of Geographic Education, Geography Standards Project, 1600 M Street, NW, Washington, DC 20036)

	Lesson Plan	Enrichment Activity
I. Seeing the World in Spatial Terms		
1. Knows and understands how to use maps, globes, and other graphic tools and technologies to acquire, process, and report information from a spatial perspective.	2-5	2, 4, 7
II. Elements: Places and Regions		
4. Knows and understands the physical and human characteristics of place.		7
IV. Human Systems		
9. Knows and understands the characteristics, distribution, and migration of human populations on Earth's surface.	4, 5	2
11. Knows and understands patterns and networks of economic interdependence on Earth's surface.	4, 5	1
12. Knows and understands the processes, patterns, and functions of human settlement.	4, 5	7

Note: Only the education goals relevant to this unit are listed.

Geography—*continued*

V. Environment and Society

14. Knows how Earth's dynamic physical and human systems are connected and interact.	4, 5	
15. Knows the consequences of the interaction between dynamic human and physical systems.	4, 5	
16. Knows changes in the meaning, distribution, and importance of resources.	2-5	1, 2

Mathematics*

(Draft National Standards, March 1989, The National Council of Teachers of Mathematics, Order Processing, 1906 Association Drive, Reston, VA 22091)

	Lesson Plan	Enrichment Activity
I. Mathematics as Problem Solving		
1. Use, with increasing confidence, problem-solving approaches to investigate and understand mathematical content.		3
X. Statistics		
1. Construct and draw inferences from charts, tables, and graphs that summarize data from real-world situations.	2-6, 8	

Science*

(Draft National Standards, February 1994, National Academy of Sciences, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418)

	Lesson Plan	Enrichment Activity
I. Science As Inquiry		
1. Identify questions and concepts that guide scientific investigation.		4
II. Physical Sciences		
2. Chemical Interactions	5-7	5
4. Conservation/Transmission of Energy		5
III. Life Science		
1. Biodiversity		6
4. Ecosystems and Human Ecology	2-9	1-7
IV. Earth & Space Science		
1. Matter/Energy in Earth Systems		5
V. Unifying Concepts And Processes Of Science		
2. Conservation		2, 3, 5, 6
VI. Science and Technology		
2. Solution Design-Cost, Risk-Benefit Analysis		5
4. Solution Evaluation		5
VII. Science and Societal Challenges		
2. Natural Resources	2-9	1-7
3. Environmental Degradation	2-9	1-7
4. Natural and Human-Induced Hazards	2-8	1-6
5. Community Health	7	4, 5,7
6. Global Change	5-9	1

Energy, Atmosphere, and Climate

On many days, visitors to the Grand Canyon can barely see the other side, because of the haze from a coal-burning power plant. According to the *Wall Street Journal*, in Mexico City, where the air was unsafe to breathe more than 300 days in 1990, school children now use gray paint for the sky in their city landscapes. While air pollution is often something you can see and feel, increases in "greenhouse gases" and ozone loss in the atmosphere are invisible and mysterious.

Given the seriousness of changes in the atmosphere, it is important to realize how our daily human activities, such as energy use, are adding pollutants to the atmosphere. Because pollutants collecting in the atmosphere trap heat, experts predict that by the year 2030, when today's students will be the world's decisionmakers, average global temperatures will have increased by 7° F (–14° C).

This lesson is based on data and analysis in WRI's *World Resources* series of reports and research done by WRI's program in Energy, Climate, and Pollution. A related WRI lesson plan is *Car Trouble*, which deals with the impact of motor vehicles on air pollution and climate change. This lesson begins by looking at energy use in industrialized and developed countries and the relationship between energy use and air pollution. The lesson identifies reasons for concern about air pollution, global warming, and ozone depletion. Finally, strategies for dealing with changes in the atmosphere are examined.

Objectives

By the time they finish this lesson, students should be able to:

- Identify human activities that are changing the Earth's atmosphere.
- Identify the major air pollutants and their sources.
- Explain why air pollution is a local, regional, and global problem.
- Compare and contrast energy use in industrialized and developing countries.
- Describe the apparent relationship between energy consumption patterns and air pollution patterns in industrialized and developing nations.
- Identify the major "greenhouse gases" and their sources.

- Communicate why there is concern about air pollution, global warming, and ozone depletion.
- Identify lifestyle/local strategies for dealing with air pollution and potential global warming.
- Identify national/international strategies for dealing with potential global warming and ozone depletion.

Teaching Strategies

Allow 2–3 class periods for this seven-part lesson. Because it is designed for flexibility, each part of the lesson may be enhanced with additional materials or enrichment activities.

The lesson includes the following materials that may be duplicated:

Student Handouts:

1 Total Energy Use by Fuel Type, 1989
2 Facts about Air Pollution
3 Facts about Global Warming and Ozone Depletion
4 Reducing Carbon Emissions

Overhead Transparency Masters:

1 Trends in Global Energy Consumption
2 How the Greenhouse Effect Works
3 Contributions to Global Warming
4 Global Fossil Fuel Consumption, 1950–90
5 Atmospheric CO_2 Concentrations, 1860–1990
6 The Greenhouse Index: 10 Countries with the Highest Greenhouse Gas Emissions, 1991
7 Stratospheric Ozone Depletion, 1979–91
8 Number of Vehicles in the World
9 Energy Intensities in Developed Countries

Beginning the Lesson

The first part of the lesson focuses on energy use. Distribute copies of **Handout 1, "Total Energy Use by Fuel Type, 1991."** The graph shows the world's countries grouped in two large categories (developing and industrialized). Three groups of developing countries are shown (Africa, Asia, and Latin America). Industrialized nations are in two categories: those belonging to the Organisation for Economic Co-operation and Development or OECD (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States) and non-OECD countries (Central Europe and the republics of the former Soviet Union).

This handout can be used as an individual, small group, or class exercise. Or, combine these three by having students first answer questions on their own and then compare and defend their answers to questions 6–11 in small groups of 3–5 students. Finally, generate a class list of all reasonable answers from all groups. Suggested answers are as follows (the answers provided for 6–11 are not the only possible answers):

1. *Which group of countries uses the most traditional fuel?* Asia.
2. *Which group of countries uses the most primary electricity?* OECD countries.
3. *Which group of countries uses the most natural gas?* OECD countries.
4. *Which group of countries uses the most oil?* OECD countries.
5. *Which group of countries uses the most coal?* OECD countries.

6. *Write one sentence that describes a similarity between OECD and non-OECD industrialized countries.* Both groups of industrialized countries use only a small amount of traditional fuels. Both groups of industrialized countries use 25–30 petajoules of natural gas. Natural gas and coal are important sources of energy in both groups of industrialized countries. Primary electricity is the 4th most important source of energy for OECD and non-OECD countries.

7. *Write one sentence that describes a difference between OECD and non-OECD industrialized countries.* OECD countries use about three times as much oil as non-OECD countries. OECD countries use more than three times as much primary electricity as non-OECD countries. OECD countries use more of every type of fossil fuel than non-OECD countries.

8. *Write one sentence that describes how African, Asian, and Latin American countries are similar.* Traditional fuels are a significant source of energy for all developing countries. All three groups of countries use less than 10 petajoules of natural gas, primary electricity, and traditional fuels.

9. *Write one sentence that describes a difference among African, Asian, and Latin American countries.* Energy use is higher in Asia than in Africa and Latin America. Coal is the most important fuel only in Asian countries. Asian countries use more oil than African or Latin American countries.

10. *Write one sentence that describes a similarity between developing and industrialized countries.* All countries use a mix of five different fuel types.

11. *Write one sentence that describes a difference between developing and industrialized countries.* Energy use is higher in industrialized than developing countries. Traditional fuels are more important in developing countries than in industrialized ones. Industrialized countries depend more on oil and natural gas than do developing countries.

Use **Overhead Transparency Master 1, "Trends in Global Energy Consumption."** These graphs compare world commercial energy use with energy use in industrialized and developing countries over time (Figure A) and per capita consumption in industrialized and developing countries over time (Figure B).

Figure A shows that, worldwide, commercial energy use has been growing steadily. In the past 20 years, consumption has increased almost 50 percent. Also, total energy use in industrial countries is far greater than in developing ones. Each person in the industrialized world uses as much commercial energy as 10 people in the developing world. However, in most developing countries, modern commercial sources of energy are consumed mainly by the industrial and transport sectors in urban areas. In rural areas, people rely on traditional fuels such as firewood, animal and plant waste, and charcoal. These traditional fuels are not usually included in international statistics and are not included in figure A or B.

There are many more people in developing countries (about 80 percent of the world's population), who together use only a fraction of what people in industrialized countries consume. Figure B shows that the world average of consumption per person is 50 gigajoules. In industrialized countries, people use 3 to 3.3 times more, and this is still increasing.

The graph shows that consumption in industrialized countries dropped when the oil embargo occurred (1974 and early 1980s), indicating that because of a combination of price increases and gasoline shortages, people in industrial countries began to conserve energy.

Identifying Sources, Trends, and Effects of Air Pollution

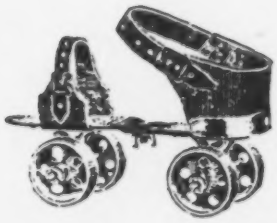
Handout 2, "Facts About Air Pollution," will help students see how energy use is affecting the lower atmosphere (troposphere). Use the fact sheet to answer questions such as:

- *What are the major air pollutants?*
- *What are their sources?*
- *How does air pollution affect human health? Have you experienced any problems related to air pollution?*
- *How does air pollution affect plants? Forests? Water?*
- *How does air pollution affect international relations?*

Suggesting Solutions for Air Pollution

Have the students use the information from this lesson and **Handout 2, "Facts About Air Pollution,"** to answer the following questions.

- *Which of your own activities have the greatest effect on air pollution? How can you modify your activities to help improve air quality?*
- *What measures would you take to reduce acid rain? What human activities would you focus on? What pollutants would you try to reduce?*
- *Which air pollutants would you seek to reduce if you were interested in making the air healthier for us to breathe? How would you do this?*
- *If you were the mayor of a large city, what steps would you take to improve your city's air quality? What activities in your city would you look at first?*
- *If you wanted to improve growing conditions for plants and forests, which aspects of air pollution would you look at first?*



Geographic Look at Air Pollution

In a discussion of air pollution, it is interesting to look specifically at where in the world these problems are occurring. Using a map of the world, discuss with students the following trends in air pollution.

- *In which regions of the world is acid precipitation a problem?* Regional acid rain is a problem in Europe and North America, and, increasingly, in China and Japan. In Europe, pollution damage to forests costs roughly US$30 billion per year. Forest damage is evident in North America and is increasing in many parts of Central Europe and the Baltic republics.
- *In which parts of the United States and Canada is acid precipitation a problem?* Primarily in New England and certain areas of New York and North Carolina, Ontario, Quebec, and Alberta.
- *In which regions of the world is air pollution most severe?* In developing countries, overall emissions of pollutants are increasing due to rising energy demand, expanding vehicle population, and increasing use of

inexpensive coal, especially in China. Many developing nations have seen increases in SO_2 or particulate levels, or both. Smog is likely to become more severe in developing countries. Levels of carbon monoxide are increasing in most of the developing world along with the increase in the number of vehicles and traffic congestion. The global vehicle population will double over the next 20–40 years to about 1 billion. Industrialized countries have made significant progress in reducing urban SO_2 and particulate levels. In Europe, North America, and Japan; SO_2 and NO_x emissions are projected to decline. Industrialized countries have reduced lead emissions, but lead contamination is a serious urban problem. Air pollution has caused serious health effects in many industrial areas of Central Europe and the former Soviet Union. Most industrialized nations and many developing nations have set legal air quality standards for some pollutants.

- *Which countries are most affected by air pollution from other countries?* Pollution from one country often causes damage in other countries: this is called transboundary pollution. European countries have been most affected by transboundary pollution and are the leaders in a series of international agreements to cut emissions, beginning with the 1979 Convention on Long-Range Transboundary Air Pollution. Only 36 percent of the 1 million metric tons of sulfur emitted in Czechoslovakia in 1987 was deposited in that country. Much of the rest came down in Poland, the Soviet Union, and other countries.

Use **Activity 4, "Monitor Air Quality,"** to study air quality in your community and/or state or province, and **Activity 2, "Investigate Your Local Energy Suppliers,"** to study local energy supplies.

Identifying Changes in the Atmosphere

Show a transparency made from **Overhead Transparency Master 2, "How the Greenhouse Effect Works."** This illustrates how gases in the atmosphere have a "greenhouse effect," trapping heat and keeping the Earth warmer than it would be otherwise. Because concentrations of greenhouse gases are increasing rapidly, there is concern about the possibility of climate change or global warming.

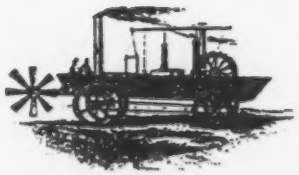
Show a transparency made from **Overhead Transparency Master 3, "Contributions to Global Warming,"** which shows how various human activities contribute to global warming. The largest category, "Energy Use," includes production and use of energy from fossil fuels—for example, electric power production and motor vehicle use. Industrial processes include cement production and manufacture of synthetic compounds, such as chlorofluorocarbons (CFCs). Deforestation also releases large amounts of carbon dioxide because carbon stored in trees and plants is released into the atmosphere when forests are cleared and burned. Agricultural activities also release greenhouse gases: flooded rice paddies are a source of methane emitted by anaerobic bacteria, and nitrous oxide is produced by bacterial action on chemical fertilizers.

Point out that human activities are not the only sources of greenhouse gases. Animals and plants exhale carbon dioxide. Swamps, marshes, tundra, and termites are sources of methane. There are also

natural processes for absorbing these gases from the atmosphere. Carbon dioxide is absorbed in the oceans and in the soils and is taken in by plants during photosynthesis. Methane is decomposed by chemical processes in the atmosphere.

Handout 3, "Facts about Global Warming and Ozone Depletion," contains additional information about the major greenhouse gases. Emphasize that the gases vary in their heat-absorbing potential. Adding a molecule of methane will trap 20–30 times as much heat as a molecule of carbon dioxide; adding a CFC molecule will trap 20,000 times as much heat as a carbon dioxide molecule. (However, new evidence shows that CFCs also have a cooling effect.)

Show transparencies made from **Overhead Transparency Master 4, "Global Fossil Fuel Consumption, 1950–90,"** and **Master 5, "Atmospheric CO_2 Concentrations, 1860–1990."** More and more greenhouse gases are being added to the atmosphere. The world's population is increasing. Energy use is rising, especially in developing countries (although these countries use far less energy than industrialized ones). Increasing use of fossil fuels has been part of the development process. **Overhead Transparency Master 6, "The Greenhouse Index: 10 Countries with the Highest Greenhouse Gas Emissions, 1991"** shows which countries are responsible for the largest percent of total emissions.



No one knows what the effect will be of adding such quantities of greenhouse gases to the atmosphere. One theory is that the Earth's climate will grow warmer, unless other climatic mechanisms counteract the warming. You may want to discuss the information provided on the volcanic eruption of Mt. Pinatubo and the significant short-term climate changes it may have created.

Predictions of possible climate change are based, in part, on long-term studies of the concentrations of carbon dioxide in the atmosphere. Scientists have made computer models to try to predict whether global warming will take place, but there are a number of unknowns, such as how the dynamics of the ocean will be affected; how cloud behavior will affect the climate; and how living systems will respond to global warming and what influence they will have on the climate.

Overhead Transparency Master 2, "How the Greenhouse Effect Works," also shows the protective layer of ozone in the upper atmosphere. While ozone is an air pollutant and a greenhouse gas in the lower atmosphere, in the upper atmosphere, its effects are beneficial. It forms a protective shield against biologically harmful ultraviolet-B (UV-B) radiation.

Show a transparency made from **Overhead Transparency Master 7, "Stratospheric Ozone Depletion, 1979–91."** Ozone losses are occurring at all latitudes, but most strikingly about the South Pole, the Antarctic "ozone hole." Peak ozone destruction during the polar spring has reached 60 percent over Antarctica. Significant ozone losses have also been found at mid-latitudes (45° corresponds to Christchurch, New Zealand in the south and Minneapolis, Minnesota in the north.) There

are preliminary indications of an Arctic ozone hole over the North Pole. Only equatorial regions so far show no significant ozone loss.

Stratospheric ozone is being depleted by atmospheric concentrations of CFCs and other ozone-destroying chemicals. Once in the upper atmosphere, a single CFC molecule can participate in the destruction of 100,000 ozone molecules. While it can take roughly 10 years before CFCs reach the stratosphere, CFCs have a life of 50 to 100 years. Because chlorine and bromine chemicals already released to the atmosphere will reach the stratosphere in coming years, ozone losses are expected to increase at least through the end of the century. Even if use of such chemicals is rapidly eliminated, full recovery of the ozone layer is not expected until about the year 2100.

Identifying Reasons for Concern about Atmospheric Changes

There is concern about potential global warming. Although exact effects are not known, it is believed that climate change would affect the following:

- *Health.* Tropical, mosquito-borne diseases such as malaria, dengue fever, and yellow fever might spread to a wider area.
- *Agriculture.* The growing season in areas of the Northern hemisphere such as Canada, Finland, Japan, and Iceland would be lengthened. However, yields of wheat, corn, and soybeans in the United States might decrease.
- *Forests.* Parasites from the tropics might extend their range and attack temperate forests. Some temperate tree species might become locally extinct.
- *Rangelands.* An ongoing decline in productivity from drought and erosion would intensify. Increased fires would be a problem.
- *Wildlife.* Many species would become extinct because their habitat would shift, shrink, or disappear.
- *Oceans.* Locations of currents and fisheries could change. Rising sea levels could flood coastal areas and threaten low-lying countries such as Bangladesh.
- *Islands.* Thirty-seven island nations, including the Caribbean islands and archipelagos around the Pacific, have formed an Alliance of Small Island States. Fearing they may disappear if the oceans rise, these states are urging action to stabilize the world's climate.

There is also concern about the potential effects of ozone loss because UV-B radiation is biologically harmful. Skin cancer rates are expected to increase—perhaps as many as 12 million more cases in the United States over the next 50 years. Other health effects will likely include an increase in cataracts and suppression of the immune system. Increasing UV-B radiation may affect marine life, disrupting some aquatic ecosystems. Many crops and plant species are likely to suffer cell damage and become less productive.

Identifying Strategies for Dealing with Air Pollution, Global Warming, and Ozone Loss

Use of fossil fuels is the largest source of greenhouse gas emissions and thus a major contributor to the threat of climate change. Any strategies to deal with air pollution and stabilize climate must involve reducing fossil fuels. Ultimately, the world will have to go through a major transition from fossil fuels to alternative energy sources. But this would be an enormous change. By 1992, fossil fuels accounted for about 90 percent of the world's commercial energy supply.

Why are motor vehicles important in any strategy to reduce air pollution and global warming? Motor vehicles cause more air pollution than any other single human activity, yet the demand for motor vehicles is growing. Show the transparency made from **Overhead Transparency Master 8, "Number of Vehicles in the World."** A large increase in demand for new vehicles is expected in developing countries where motor vehicles are already a serious problem in many urban areas. In Mexico City—the city with the world's worst air pollution—motor vehicles are by far the main pollution source.

What are some ways to reduce pollution from motor vehicles? Conservation strategies include developing energy-efficient cars, decreasing automobile use by carpooling, developing vehicles that use alternative fuels such as electricity, setting and enforcing emission standards, using alternative transportation (public transportation, bicycling, walking), and promoting the construction and use of mass transit.

Both short- and long-term strategies for reducing the environmental effects of motor vehicles are explored in the lesson *Car Trouble* in the 1994 *Teacher's Guide to World Resources*.

Other major sources of air pollution are industries and power plants. Techniques for decreasing pollution from these stationary sources include:

- Closing the worst polluters [underway in (East) Germany's chemical industry].
- Switching to low-sulfur fuel (as in Mexico City) or natural gas.
- Installing pollution-control devices such as scrubbers. (Such devices reduce air pollutants, but not the amount of CO_2 released.)
- Changing manufacturing processes to cut emissions. (The auto industry has begun to use water-based paints that don't emit hydrocarbons.)
- Setting and enforcing emissions standards.

For countries that use a lot of energy, the best and cheapest method is ENERGY CONSERVATION.

Countries vary greatly in their energy intensity—the ratio of energy required to produce one dollar (U.S.) of gross domestic product (GDP). Generally, the OECD countries have achieved more efficient energy use during the past 20 years. Japan, Denmark, and the United Kingdom have improved their energy intensities by over 30 percent. Japan has become the most energy efficient, and the United States is one of the

least energy efficient. **Overhead Transparency Master 9, "Energy Intensities in Developed Countries,"** shows that OECD countries in Europe, as a group, are the most energy efficient, compared with North America and OECD Pacific countries. And yet, these countries have continued to improve living standards while reducing energy consumption.

Reductions in the use of fossil fuels must be part of strategies to prevent global warming. Switching to less carbon-intensive fuels will help (coal produces about 80 percent more CO_2 per unit of energy than natural gas and about 25 percent more than oil). Using carbon-free energy sources, such as wind and sunlight, is another possibility. Slowing deforestation, which releases CO_2, and planting new forests is another strategy. A third strategy is altering agricultural practices (developing new strains of rice that don't need flooding, enclosing manure piles and feedlots to capture methane).

Phasing out CFCs is an important strategy to prevent ozone loss. This requires both technology and international cooperation. Alternatives have been found for nearly all the major product uses of CFCs. The Montreal Protocol on Substances that Deplete the Ozone Layer has set strict timetables for CFC phaseout and established rules governing international trade in ozone-destroying chemicals and CFC products. By July 1991, about 70 nations, representing over 90 percent of global CFC production and consumption, had signed. But there is enormous potential demand for CFCs in developing countries where more than 75 percent of the world's population lives. The cost of transferring new technologies will be high.

Whether a CFC phaseout will help prevent global warming is now uncertain. CFCs do contribute to warming, but they also destroy ozone, another greenhouse gas. It now seems that the decreased stratospheric ozone may exert a cooling effect on the lower atmosphere that may offset the warming attributed to CFCs.

Concluding the Lesson

Air pollution, global warming, and ozone loss may seem like such big problems that students cannot do anything to deal with them. But students and their families can make choices. Their own actions do have some effect. About one third of the energy consumed in the United States is used by individuals in their homes and cars. By using energy, students contribute to air pollution and "greenhouse gases." For example, watching five hours of television or using a 1500-watt hair dryer for an hour results in the emission of one pound of carbon. **Activity 3, "Keep an Energy Diary,"** will help students take a close look at the ways in which they use energy. This activity may help them identify ways they might alter their lifestyles in order to reduce energy consumption. **Handout 4, "Reducing Carbon Emissions,"** can be used to help students make an energy conservation plan.

1 Examine the Convention on Climate Change

Take a look at the actual text of the Convention on Climate Change negotiated over 1991 and 1992 by 150 nations and signed at and after the 1992 Earth Summit in Rio de Janeiro. The convention is available from the Information Program on Sustainable Development, Room S-1037, United Nations, New York, New York, 10017. Discuss in class: What does signing the convention bind nations to do? By when? What effect will these actions have on global warming? Divide the class into "delegations" from fictitious countries—at least one industrialized country, one poor country, and one rapidly industrializing country. Have them study the convention and determine how it will impact them.

Skills emphasis:* *Geo IV 11, V 16; Civics IV 1, IV 3; Science III 4, VII 2–4, VII 6*

Suggested for use in: *Social Studies, Political Science, History, Civics, International Studies.*

2 Investigate Your Local Energy Suppliers

Have students contact the local power companies (public gas and electric, as well as privately owned coal and home heating oil companies) to trace the source of your town's energy supply. How is energy generated by these companies? Have there been significant changes in their supply/demand? How have costs changed in the last few years? Have these companies modified operating methods in recent years to address environmental issues? Are there any specific programs to promote energy conservation? What are the main environmental impacts of power generation?

Skills emphasis: *Geo I 1, IV 9, V 16; Science III 4, V 2, VII 2–4*

Suggested for use in: *Social Studies, Earth Science, Geography.*

3 Keep an Energy Diary

About 11,000 pounds (4,990 kilograms) of carbon or its heating equivalent are added to the atmosphere each year for each person in the United States. To help students identify ways in which their use of energy contributes to carbon emissions, have them keep a record of their energy use for one day. For example, they should record the appliances they use (radio or TV, toaster, hair dryer, etc.) and the amount of time the appliance is used, the length of time they use electric lights, how many miles they drive or are driven in a car (burning a single tank of gasoline produces 300–400 pounds of carbon dioxide, the most important greenhouse gas), etc. Once they have recorded their energy use, students should analyze it. In what ways could they save energy? (See **Handout 4, "Reducing Carbon Emissions."**) Will any of these changes cost money? Will any of them save money?

Skills emphasis: *Math I 1; Science III 4, V 2, VII 2–4*

Suggested for use in: *Social Studies, Earth Science, Environmental Issues.*

4 Monitor Air Quality

Ask students to hypothesize whether local air quality is getting better or worse. Have students monitor air quality over a period of time. Usually, a report on air quality is available in the newspaper or through the telephone weather forecast number. Record each day's reading on a graph for one month. If figures are available, compare with the same month for the previous five years. Recording air quality statistics will help students identify particular pollutants such as sulfur dioxide. Have students research the major sources of local air pollution (auto emissions, power plants, factories). At what times of year does the worst air pollution occur? Join other students around the world monitoring air pollution, global warming, and ozone depletion and sharing their findings over telecommunications networks. For information and curriculum materials, contact TERC, 2067 Massachusetts Avenue, Cambridge, MA 02140. Phone (617) 547-0430.

Skills emphasis: *Geo I 1; Science I 1, III 4, VII 2, VIII 3–5*

Suggested for use in: *Chemistry, Geography, Environmental Issues, Social Studies, Earth Science.*

5 Study Alternative Sources of Energy

Many types of nonfossil energy sources are already in use: solar-thermal heating, solar-thermal power, wind energy, and geothermal heat. Have students choose one of these energy sources and research the question: Can alternative sources of energy provide a significant percentage of our energy needs in the next 25 years? Where are these sources being used? Are there any problems in using these types of energy? What are the costs? Photovoltaic power may become important in the future. Also, a new generation of advanced nuclear technologies may become important if the problems of safety and radioactive wastes can be solved.

Skills emphasis: *Science II 2, II 4, III 4, IV 1, V 2, VI 2, VI 4, VII 2–5*

Suggested for use in: *Chemistry, Environmental Issues, Earth Science.*

**See chart of Draft National Performance Standards at beginning of this unit.*

6 Plant a Tree

Trees planted in an urban area not only take up carbon dioxide but shade buildings in hot weather and shield them from winds in cold weather, reducing air conditioning and heating demands—and, thus, electricity generation, much of which comes from burning fossil fuels. A single tree can absorb 36 pounds (16 kilograms) of carbon per year from the air. Encourage students, either individually or as a group, to identify places where trees could be planted. Do research to find out what types of trees are appropriate and what type of care the trees require. If possible, students should plant and care for trees, either at home, or at school. American Forests has a "Global Releaf" program (Box 200, Washington, D.C. 20013 or Global Releaf–Canada, 251 Laurier Ave., West, Suite 701, Ottowa, Ontario, Canada). For a free fact sheet on launching a tree-planting campaign, write the Trust for Public Land, 116 New Montgomery, 4th Floor, San Francisco, CA 94105. Ask for the *Step-by-Step Guide to Organizing a Releaf Effort.*

Skills emphasis: *Science III 1, III 4, V 2, VII 2, VII 3, VII 4*

Suggested for use in: *Biology, Ecology, Environmental Science, Earth Science.*

7 Promote Bicycling

Students might develop ideas for where new bike paths should be installed in the community, both for everyday transportation and recreation. Take a local map and mark them in. The Bicycle Federation of America, 1818 R Street N.W., Washington D.C. 20009 has fact sheets telling how to promote local bicycling programs. Send a self-addressed stamped envelope. Is there an abandoned railroad track in your Community? The Rails-To-Trails Conservancy works with local groups to convert old railroad right-of-ways into hiking and biking trails. For more information, write: Rails-To-Trails Conservancy, 1400 16th Street N.W., Suite 300, Washington, D.C., 20036.

Skills emphasis: *Geo I 1, II 4, IV 12; Civics V 4; Science III 4, VII 2, VII 3, VII 5*

Suggested for use in: *Social Studies, Geography, Health and Physical Education.*

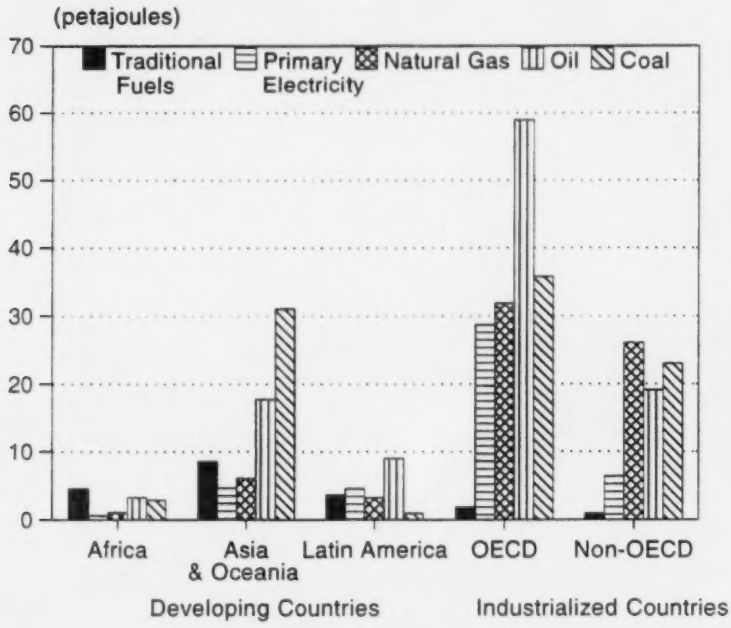
Suggestions for Further Reading

- American Solar Energy Society, *Science Projects in Renewable Energy and Energy Efficiency* (National Energy Foundation, Salt Lake City, Utah, 1991).
- Gary Bryner, *Blue Skies, Green Politics: The Clean Air Act of 1990,* (Congressional Quarterly Books, Washington, D.C., 1992).
- *Energy, Technology, and Society, 45 min. video, teacher resource guide, IBM- or Apple II-compatible software, fact sheet, and posters (Victorian Solar Energy Council, Bullfrog Films). Five interdisciplinary units: Introduction to Energy; Solar Energy; Biomass Energy; Wind, Water and Geothermal Energy; and Energy and the Future.*
- John Firor, *The Changing Atmosphere: A Global Challenge* (Yale University Press, New Haven, CT, 1990).
- *Global Resources: Opposing Viewpoints, Matthew Polesetsky, ed. (Greenhaven Press, Inc., San Diego, California, 1991).*
- June D. Hall and Arthur J. Hanson, *A New Kind of Sharing: Why We Can't Ignore Global Environmental Change,* (International Development Research Centre, Ottawa, Ontario, Canada, 1992).
- Keith L. Kozloff and Roger C. Dower, *A New Power Base: Renewable Energy Policies for the Nineties and Beyond,* (World Resources Institute, Washington, D.C., 1993).
- Richard L. Wyman, Global Climate Change and Life on Earth, (Routledge, Chapman and Hall, New York, 1991).
- Louise B. Young, *Sowing the Wind: Reflections on the Earth's Atmosphere* (Prentice-Hall, New York, 1990).

Audiovisual Resources

- *A World of Energy 1,* (1981), 69 min., National Film Board of Canada. *Comprehensive look at applications of solar, thermal, biomass, and atmoic energy.*
- A World of Energy 2, (1985), 48 min., National Film Board of Canada. *Wind energy, solar energy, and energy from the ground.*
- *Greenhouse Crisis: The American Response,* 11 min., VHS, The Video Project. *This video illustrates the relationship between energy consumption, the greenhouse effect, and global warming.*
- *Power Struggle,* 58 min., VHS, Public Policy Productions for WNET, Bullfrog Films. *How to choose energy sources. Narrated by Meryl Streep.*

Total Energy Use by Fuel Type, 1991



Source: United Nations Statistical Division (UNSTAT), "U.N. Energy Tape" on diskette (UNSTAT, New York, 1993). Note: Traditional Fuels include wood, charcoal, animal and vegetable waste. Primary Electricity includes hydro, geothermal, wind, and nuclear power generation.

This exercise is based on information in the graph above. To compare energy used by industrialized and developing countries, first answer these five questions:

1. Which group of countries uses the most traditional fuel?
2. Which group of countries uses the most primary electricity?
3. Which group of countries uses the most natural gas?
4. Which group of countries uses the most oil?
5. Which group of countries uses the most coal?

Now, look for similarities and differences in the energy used by these countries. State these in your own words, following the directions below.

6. Write one sentence that describes a similarity between OECD and non-OECD industrialized countries.
7. Write one sentence that describes a difference between OECD and non-OECD industrialized countries.
8. Write one sentence that describes how African, Asian, and Latin American countries are similar.
9. Write one sentence that describes a difference among African, Asian, and Latin American countries.
10. Write one sentence that describes a similarity between developing and industrialized countries.
11. Write one sentence that describes a difference between developing and industrialized countries.

Measuring Energy

Joules are the basic metric unit of energy measurement used throughout the world. The British Termal Unit (BTU) is more familiar to U.S. students. A BTU is about the same as a kilojoule (1,000 joules). Both equal about 250 calories or the quantity of heat required to raise the temperature of a pint of water 1° F (–17° C).

Large amounts of energy are measured in the units below:

megajoule: 1,000,000 (1 million) joules

gigajoule: 1,000,000,000 (1 billion) joules

terajoule: 1,000,000,000,000 (1 trillion) joules

petajoule: 1,000,000,000,000,000 (1 quadrillion) joules

exajoules: 1,000,000,000,000,000,000 (1 quintillian) joules

For comparison: The world's average energy consumption per capita is 50 gigajoules. The total world energy

Facts about Air Pollution

Historically, air pollution has been a local problem. Small factories produced relatively small amounts of pollutants capable of causing local environmental damage. These pollutants rarely traveled far or caused widespread damage.

More recently, as industrialization and the use of automobiles has increased, air pollution has become a more regional and global problem. Even in the sparsely populated western United States, air pollution often makes it impossible to see across the Grand Canyon. In 1991, pollutants from burning oil wells in Kuwait spread across much of the Middle East and south central Asia.

Much of the world's urban population breathes unhealthy air at least some of the time. Polluted air is especially dangerous for sensitive groups such as children and the elderly. Air pollutants irritate the respiratory system and impair lung function. Air pollution causes environmental damage both to the urban environment by damaging buildings and to the natural environment. Polluted air damages and kills trees, crops, and other plants. Air pollution contributes to water pollution because many airborne contaminants eventually end up in rivers and lakes.

There are two types of pollutants: gases and particulates (solid and liquid material suspended in the air). The following table describes the main pollutants, their sources, and environmental and health effects.

Pollutant	Description	Impact	Sources
Sulfur Dioxide (SO_2)	Released when fossil fuels are burned.	Contributes to acid precipitation; damages buildings; causes respiratory problems.	Coal-burning power plants (65 percent), other combustion (18 percent, includes unvented heating and cooking sources), factories (13 percent), transportation (3 percent), other (1 percent).
Nitrogen Oxides (NO_x)	Released when fossil fuels are burned; react with volatile organic compounds in the presence of sunlight and heat to form smog.	Contribute to acid precipitation and smog; cause stinging eyes, coughing, increased asthma attacks, and greater susceptibility to infection. Also are toxic to plants.	Transportation (41 percent), coal-burning power plants (29 percent), other combustion (24 percent), factories (3 percent), other (3 percent).

Facts about Air Pollution *(continued)*

Pollutant	Description	Impact	Sources
Carbon Monoxide (CO)	Created by the incomplete combustion of carbon-containing fuels.	Contributes to ozone formation. When inhaled, can interfere with the body's ability to carry oxygen in the bloodstream.	Motor vehicle exhaust.
Volatile Organic Compounds (VOCs)	Combine with NO_x to form smog.	Eye irritation, respiratory irritation, and even cancer.	Transportation (41 percent), other industrial processes (19 percent), fuel combustion (13 percent), industrial surface coatings (10 percent), miscellaneous solvents (10 percent), oil storage (7 percent).
Particulates	Pieces of ash or smoke, soot, dust, and liquid droplets.	Contributes to respiratory disease.	Emitted during burning of fuels from dust, forest fires, conversion of SO_2 to sulfate.
Lead	Airborne lead particulates come primarily from auto exhaust. Can also be ingested through food and water.	Cumulative effects include circulatory, reproductive, nerve, and kidney damage. Children are especially susceptible.	Leaded gasoline, lesser amounts from metal smelters, and manufacture of batteries.
Ozone	Formed when NO_x reacts with VOCs.	At ground level (as smog), threatens public health, injures trees, crops, other vegetation. In the stratosphere, acts as a filter, screening out harmful ultraviolet rays. (See **Handout 3.**)	Formed in the air by reaction between nitrogen oxides and volatile organic compounds.

Facts about Global Warming and Ozone Depletion

The Earth's atmosphere, a thin blanket of gases, protects the planet from the harshest of the sun's ultraviolet radiation. The atmosphere, by trapping the Earth's warmth, keeps rivers and oceans from freezing. Carbon dioxide and water vapor are the most important gases in creating the insulating or "greenhouse effect" of the atmosphere.

The amount of carbon dioxide in the atmosphere has been increasing rapidly. Human activities are also releasing other "greenhouse" gases such as methane, ozone, and chlorofluorocarbons (CFCs), which intensify the heat-trapping properties of the atmosphere as a whole. CFCs also rise into the upper layer of the atmosphere, the stratosphere, where they destroy the protective layer of ozone, a gas that forms a shield against ultraviolet rays that can harm many forms of life.

About 1 million tons (over 900,000 metric tons) per year of CFCs have been released worldwide since the mid-1970s. In the lower atmosphere, CFCs contribute to global warming, but in the stratosphere, they trap ozone molecules, degrading the protective shield. In 1991, scientists concluded that decreased stratospheric ozone has a cooling effect on the lower atmosphere that may be large enough to actually offset part of the warming from greenhouse gases. If the warming effect of CFCs is offset by the newly discovered cooling effect, then phasing out CFC use will not decrease global warming. However, a phaseout will still protect the stratospheric ozone layer.

Concern is growing that atmospheric changes could bring on rapid, profound climatic changes.

Sources and Types of the Most Important Greenhouse Gases

Carbon Dioxide (CO_2): released by the burning of fossil fuel (oil, coal, and natural gas), flaring of natural gas, changes in land use (deforestation, burning and clearing land for agricultural purposes), and the manufacturing of cement. Accounts for one half of the warming potential caused by human activity.

Methane (CH_4): sources include landfills, wetlands and bogs, domestic livestock, coal mining, wet rice growing, natural gas pipeline leaks, biomass burning, and termites. Molecule for molecule, methane traps heat 20–30 times more efficiently than CO_2. Within 50 years, it could become the most significant greenhouse gas.

Chlorofluorocarbons (CFCs): industrial products developed 60 years ago. Used in refrigerators, automobile air conditioners, solvents, aerosol propellants, insulation. The most powerful of the greenhouse gases—in the atmosphere, one molecule of CFC has about 20,000 times the heat-trapping power of a molecule of carbon dioxide. In the upper atmosphere or stratosphere, CFCs degrade the ozone layer. One CFC molecule can trap as many as 100,000 ozone molecules. The thinning of the ozone layer may have a cooling effect on the lower atmosphere. It also allows penetration of more ultraviolet rays, which can cause skin cancers and cataracts in humans as well as damage to plants.

Nitrous Oxide (N_2O): sources include burning of coal and wood, and soil microbes' digestion. Long-lasting gas that eventually reaches the stratosphere where it helps destroy the ozone layer.

Ozone (O_3): an unstable form of oxygen. Produced by photochemical processes in the atmosphere when nitrogen oxides react with organic compounds. In the lower atmosphere, ozone is a greenhouse gas. (In the upper atmosphere, ozone absorbs much of the sun's damaging ultraviolet rays.)

Trends

Atmospheric concentrations of greenhouse gases are rising at unprecedented rates. Greenhouse gas emissions from developing countries are expected to increase rapidly.

Large-scale climate changes may occur unless other climatic systems counteract the warming effect of the greenhouse gases.

The eruption of the Mt. Pinatubo volcano in the Philippines in June 1991 sent a huge volume of ash and sulfur dioxide (SO_2) into the stratosphere that could temporarily change the Earth's climate. In a single eruption, the volcano emitted almost 20 million tons (18,144,000 metric tons) of SO_2—nearly as much as the entire SO_2 emissions of the United States in one year. Sulfur dioxide creates a haze of sulfuric acid that reflects and scatters sunlight. Experts think this haze might lower average global temperatures by more than 0.3° F (0.2° C) for three or four years, enough to mask global warming.

Facts about Global Warming and Ozone Depletion *(continued)*

Total global energy use is projected to grow at an annual rate of 1.5–2 percent. Nonfossil energy sources are likely to become more important because of concern over global warming.

Cleaner, more efficient energy technologies can significantly reduce greenhouse gases from fossil fuels, especially over the next 20 years. However, total greenhouse gas emissions are likely to increase due to expanded energy use.

Demand for refrigeration (which has cooling systems that use CFCs) in developing countries is projected to increase greatly, especially in China and India.

Ozone losses in the upper atmosphere are occurring at all latitudes in both hemispheres. The most striking example of ozone loss occurs over the South Pole during September and October. As ozone is lost, the amount of biologically harmful UV-B radiation will increase. Skin cancer rates are expected to increase. Other health effects will likely include an increase in cataracts and suppression of the immune system. Increased UV-B radiation may also harm plants.

The international community is taking steps to control and ultimately ban production of CFCs by the year 2000. By July 1991, about 70 nations (including Canada and the United States) had signed the Montreal Protocol on Substances That Deplete the Ozone Layer (1987). These nations represent over 90 percent of global CFC production and consumption.

Some developing countries are quickly phasing out CFC use. Others refuse to sign this treaty because they fear switching to ozone-friendly technology will be too expensive and hamper their development. A fund, financed by the largest CFC users, has been set up to compensate developing countries for the added costs of doing without CFCs.

Talking About Energy, Atmosphere, and Climate Change

British thermal unit (Btu)—a unit of heat equal to about 252 calories; the quantity of heat required to raise the temperature of one pound of water (about 1 pint or 0.5 kilograms) one degree Fahrenheit (0.6° C). One Btu equals 1,055 joules or about 1 kilojoule.

commercial fuels—fuels used commercially include the fossil fuels: oil, coal, and natural gas; nuclear energy; and hydro, wind, and geothermal power.

energy intensity—the amount of energy needed to produce one dollar (U.S.) of gross domestic product.

exajoule—1 quintillion (1,000,000,000,000,000,000) joules.

gigajoule—1 billion (1,000,000,000) joules.

gross domestic product—the sum of the final outputs of the various sectors of the economy (agriculture, manufacturing, government services, etc.) after subtracting inputs to production. Gross domestic product includes only domestic production. Gross national product includes overseas production.

joule—0.0009478 Btus. The basic metric unit of energy measurement.

kilojoule—1,000 joules.

megajoule—1 million (1,000,000) joules.

petajoule—1 quadrillion (1,000,000,000,000,000) joules.

primary electricity—a way of measuring hydro, geothermal, wind, and nuclear electrical power generation in terms of how much fossil fuel it would take to produce the same amount of electricity.

renewable fuel—fuels that are not used up, such as solar, wind, and hydropower, and fuels that can be regrown, such as biomass.

terajoule - 1 trillion (1,000,000,000,000) joules.

traditional fuel - includes wood, charcoal, and animal and vegetable waste. Because it is difficult to monitor, traditional fuel use is not included in most assessments of national, regional, or global energy use.

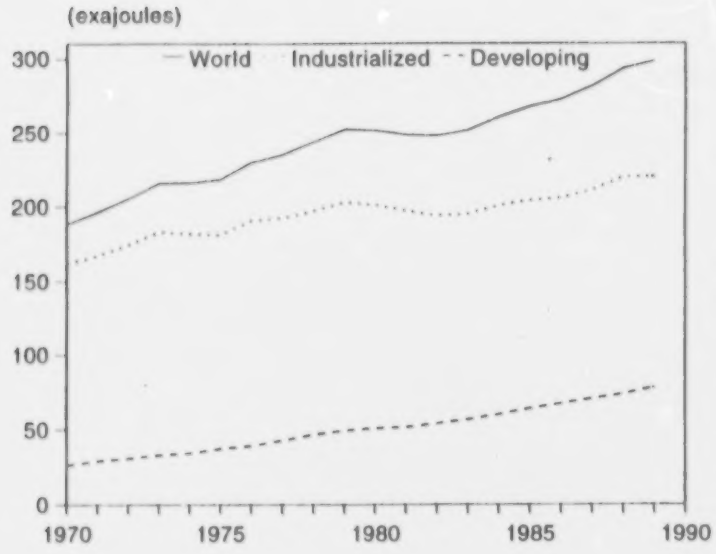
Reducing Carbon Emissions

The United States emits 1.4 billion tons (1.3 billion metric tons) of carbon annually. With a U.S. population of 252 million, that's 5.5 tons (6 metric tons) per person per year. Canada emits 12 million tons (11 million metric tons) of carbon annually. Granted, much of this total comes from industry, but carbon output can be reduced by making everyday decisions to use energy in a way that produces less carbon. By rating yourself on the following chart, see how many ways you can conserve energy to slow global warming! (General rule of thumb: If you save 1 kilowatt-hour, that represents a savings of 0.4 pounds (0.2 kilograms) of carbon not released to the atmosphere.)

Activity	Annual Energy Savings	Annual Reduction in Carbon Emissions
Home		
Improving insulation in your hot water heater	300 kilowatt-hours (kwh)	120 lb. (54 kg.)
Switching from resistance heater to heat pump	2,000 kwh	800 lb. (363 kg.)
Switching from typical refrigerator/freezer to more efficient model	1,250 kwh	500 lb. (227 kg.)
Updating central air conditioning	1,000 kwh	400 lb. (181 kg.)
Substituting an 18-watt compact fluorescent light for a 75-watt regular bulb (8 hours/day)	170 kwh	70 lb. (32 kg.)
Car		
Carpooling instead of driving alone, for five friends	1,000 gallons gasoline (3,785 liters)	5,000 lb. (2,268 kg.)
Taking inter-city train instead of air flight	2 gallons oil per 100 miles (8 liters oil per 161 kilometers)	10 lb. per 100 miles (5 kg. per 160 kilometers)
Not driving (the average U.S. car goes 10,000 miles or 16,093 kilometers per year)	500 gallons (1,893 liters)	2,650 lb. (1,202 kg.)
Driving a car with 30 mpg (8 liters per 100 km.) instead of a car with 20 mpg (12 liters per 100 km.) for 10,000 miles (16,093 kilometers)	167 gallons (632 liters)	880 lb. (399 kg.)
Driving a car with 40 mpg (6 liters per 100 km)	250 gallons (946 liters)	1,320 lb. (599 kg.)
Driving a car with 50 mpg (5 liters per 100 km)	300 gallons (1,136 liters)	1,580 lb. (717 kg.)
Tuning up your car (at average 500 gallons/yr. or 189 liter/yr.)	50 gallons/yr. (189 liters)	265 lb. (120 kg.)
Community		
Using a push mower instead of power lawn mower	5 gallons gasoline (19 liters)	26 lb. (12 kg.)
Planting trees to the south and west of your home	500–1,500 kwh	1,000 lb./yr. (454 kg./yr.) (from both carbon stored in trees and energy saved from reduced air conditioning)

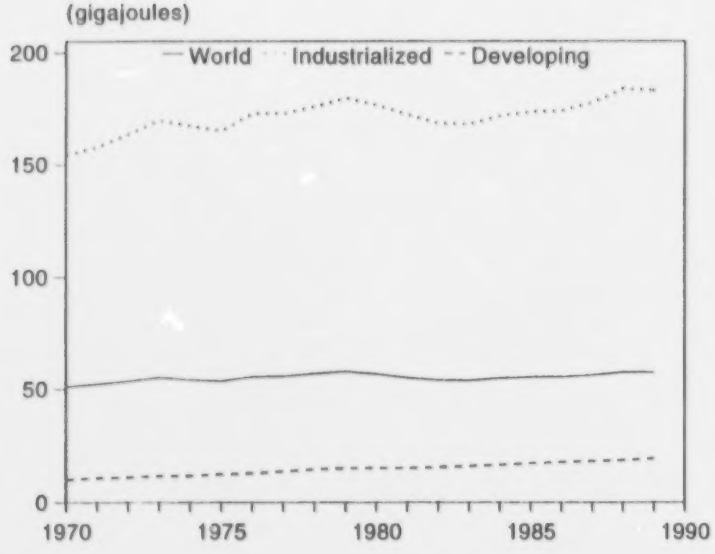
Trends in Global Energy Consumption

a. Commercial Energy Consumption



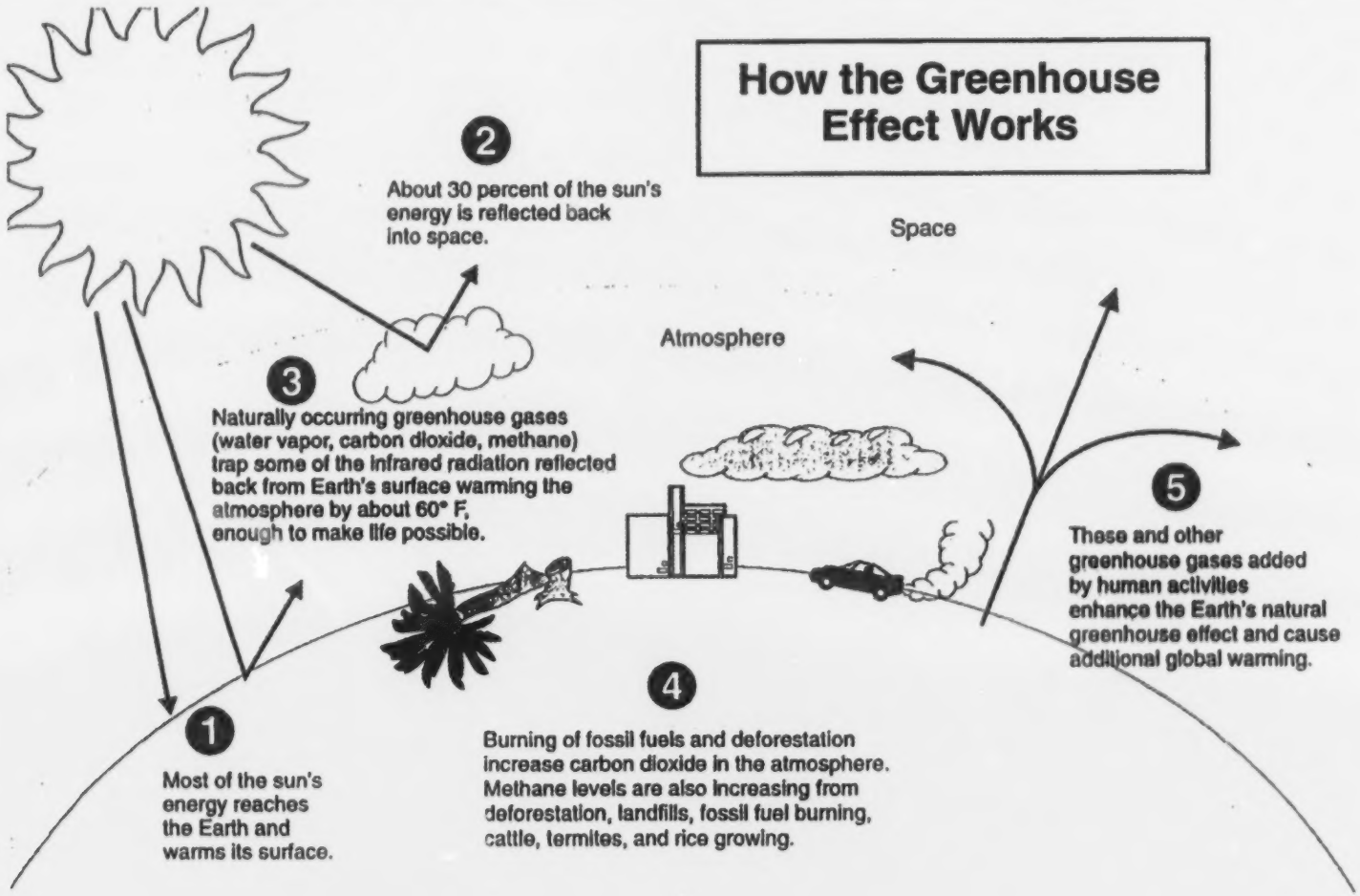
Source: United Nations Statistical Division (UNSTAT), *U.N. Energy Tape* on diskette (UNSTAT, New York, 1993).

b. Commercial Energy Consumption Per Capita



Source: United Nations Statistical Division (UNSTAT), *U.N. Energy Tape* on diskette (UNSTAT, New York, 1993); United Nations Population Division (UNPD), "Interpolated National Populations (The 1992 Revision)" on diskette (UNPD, New York, 1992).

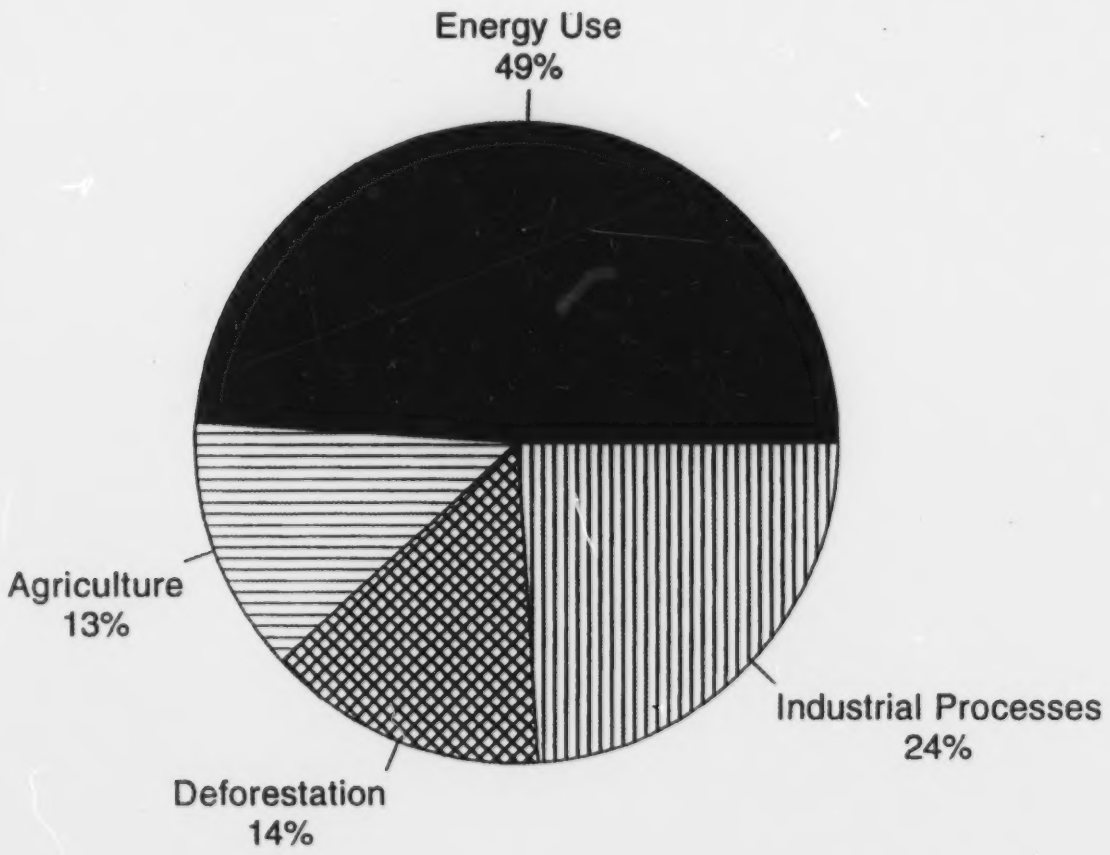
How the Greenhouse Effect Works


2
About 30 percent of the sun's energy is reflected back into space.
Space
Atmosphere
3
Naturally occurring greenhouse gases (water vapor, carbon dioxide, methane) trap some of the infrared radiation reflected back from Earth's surface warming the atmosphere by about 60° F, enough to make life possible.
5
These and other greenhouse gases added by human activities enhance the Earth's natural greenhouse effect and cause additional global warming.
4
Burning of fossil fuels and deforestation increase carbon dioxide in the atmosphere. Methane levels are also increasing from deforestation, landfills, fossil fuel burning, cattle, termites, and rice growing.
1
Most of the sun's energy reaches the Earth and warms its surface.

Computer Graphics by Susanne Kamalieh

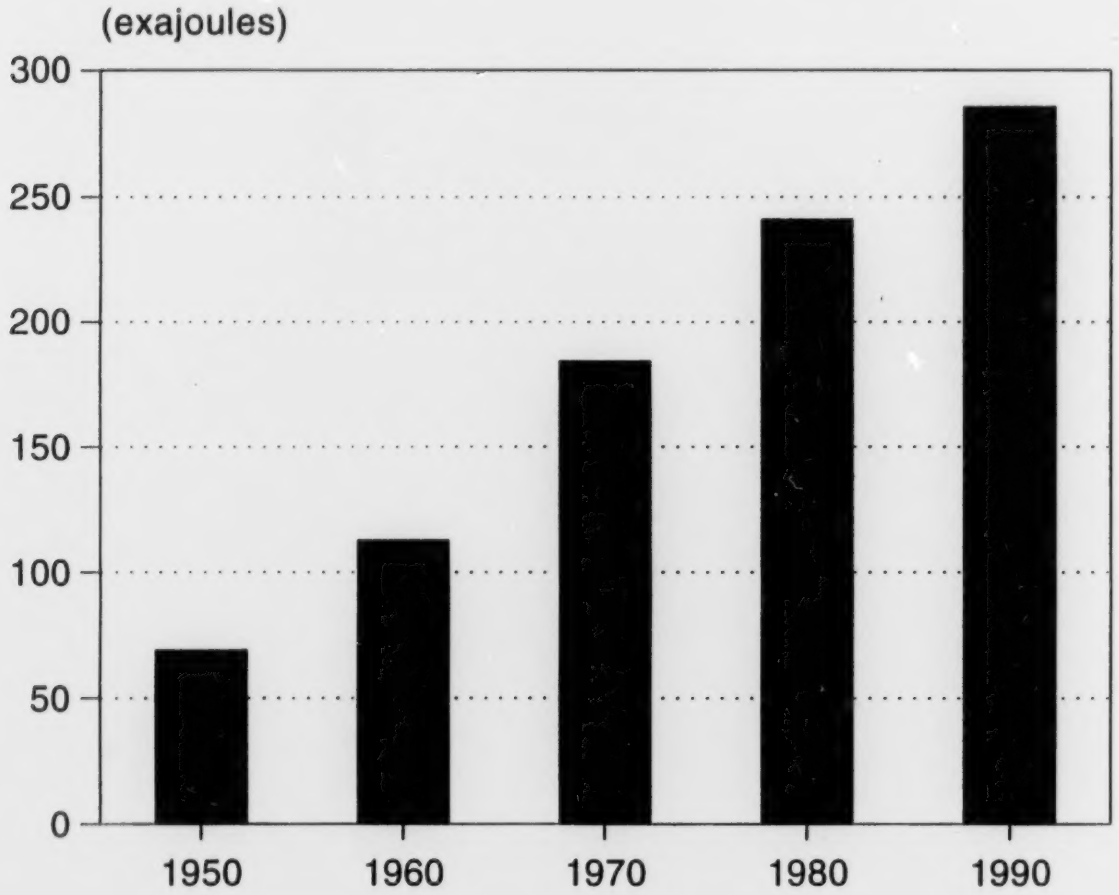
Source: World Resources Institute, 1989.

Contributions to Global Warming by Human Activity



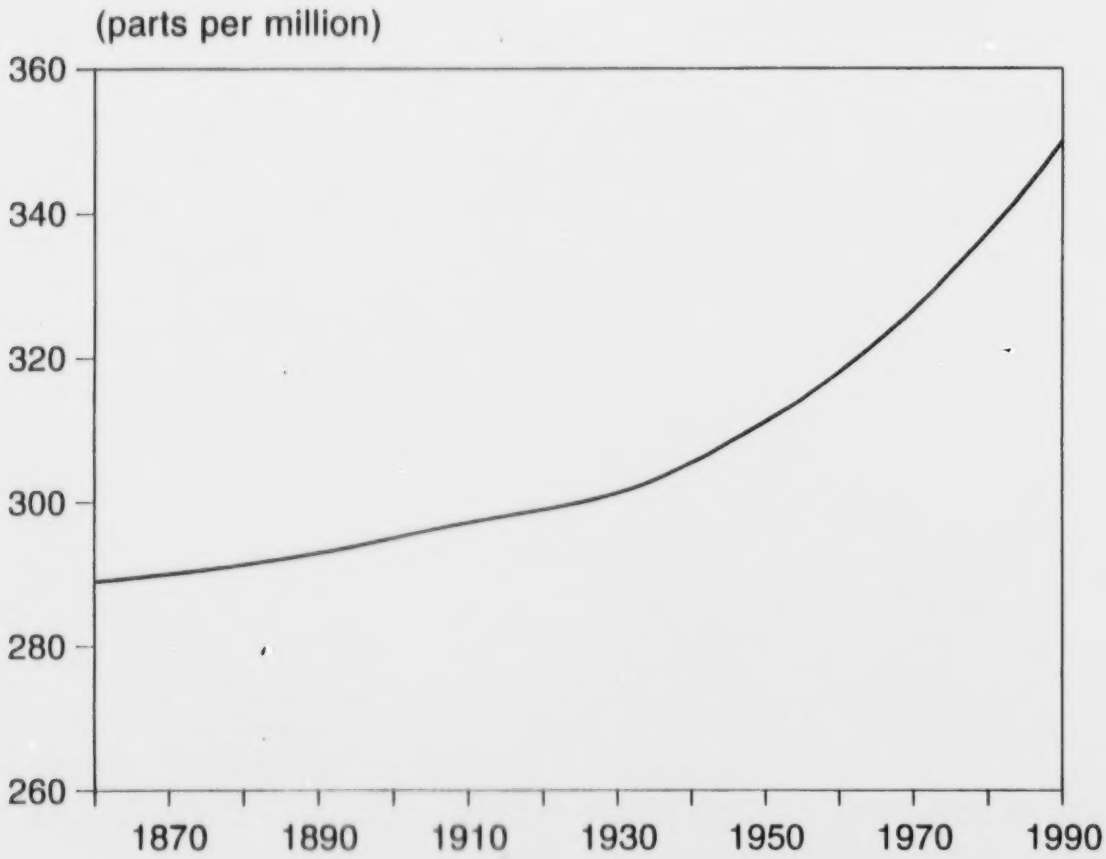
Source: World Resources Institute in collaboration with the United Nations Environmental Programme and the United Nations Development Programme, *World Resources 1990-91* (Oxford University Press, New York, 1990), Table 2.4, p. 24.

Global Fossil Fuel Consumption, 1950–90



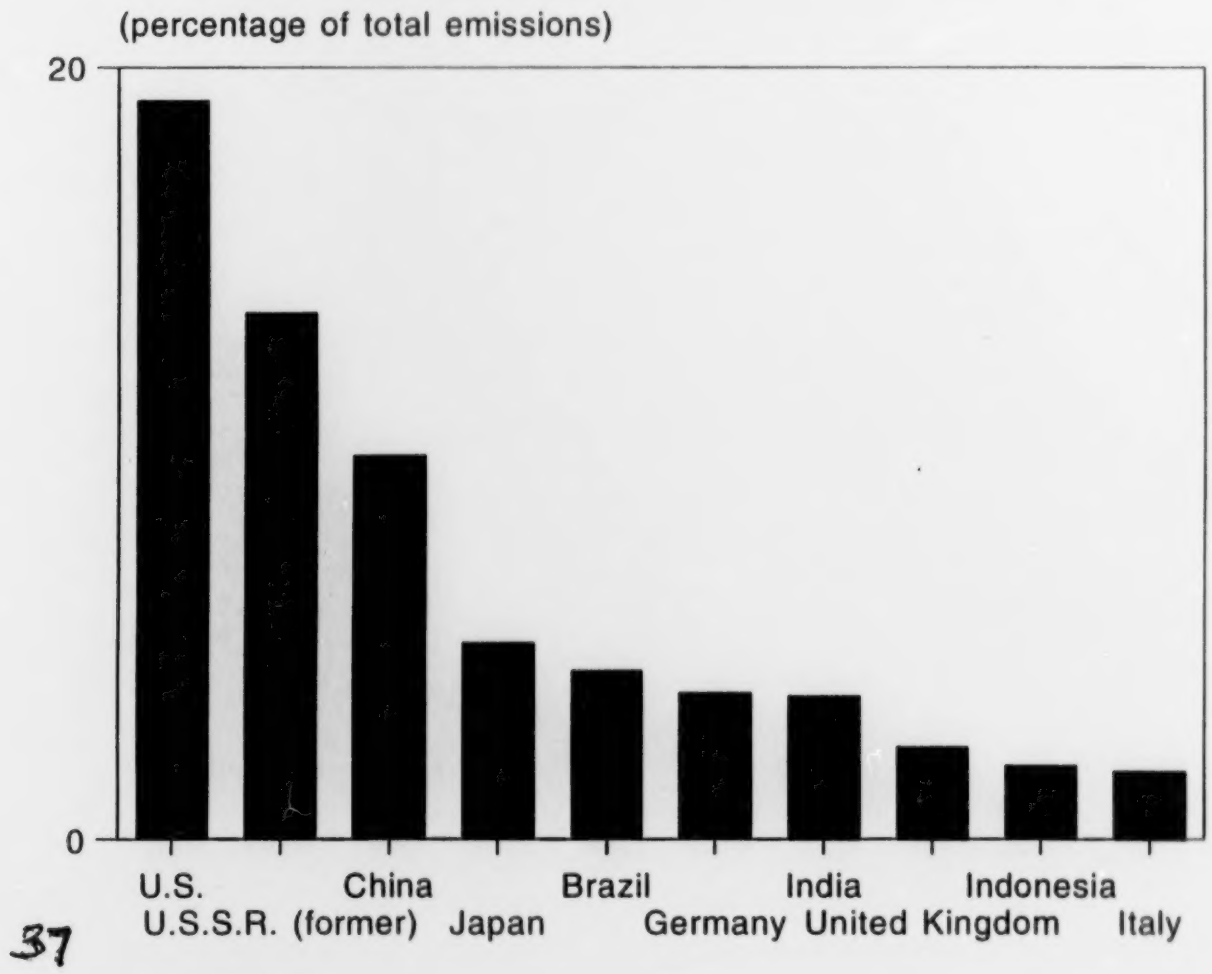
Sources: United Nations (U.N.), "Energy Statistics Yearbook 1982" (U.N., New York, 1984); United Nations Statistical Division (UNSTAT), *U.N. Energy Tape* on diskette (UNSTAT, New York, 1993).

Atmospheric CO_2 Concentrations, 1860–1990



Source: Intergovernmental Panel on Climate Change (IPCC), *Climate Change: The IPCC Scientific Assessment*, J.T. Houghton, G.J. Jenkins, and J.J. Ephraums, eds. (Cambridge University Press, Cambridge, U.K., 1990), p. xvi.
Note: The line in this graph represents the average annual concentration of CO_2. Actual CO_2 levels fluctuate.

Greenhouse Gas Emissions, 1991



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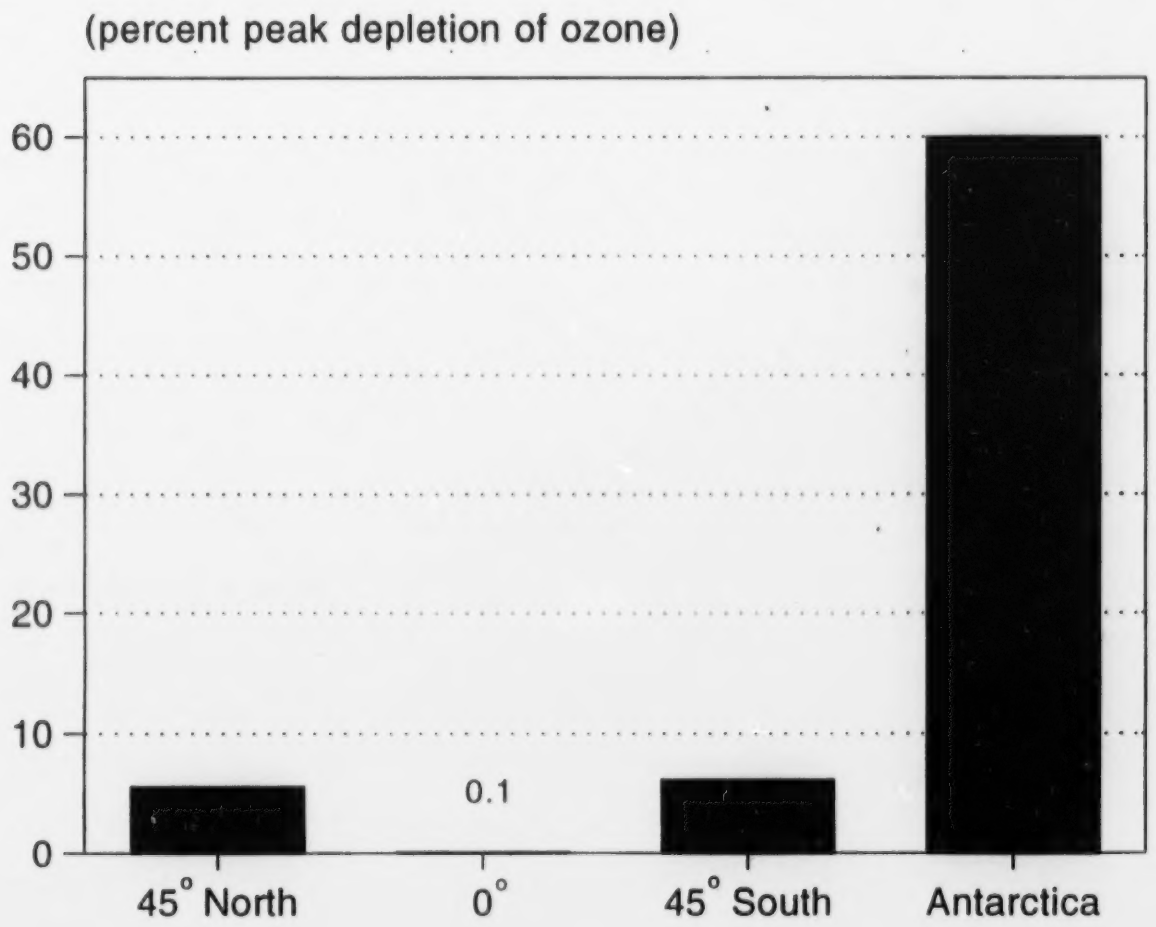
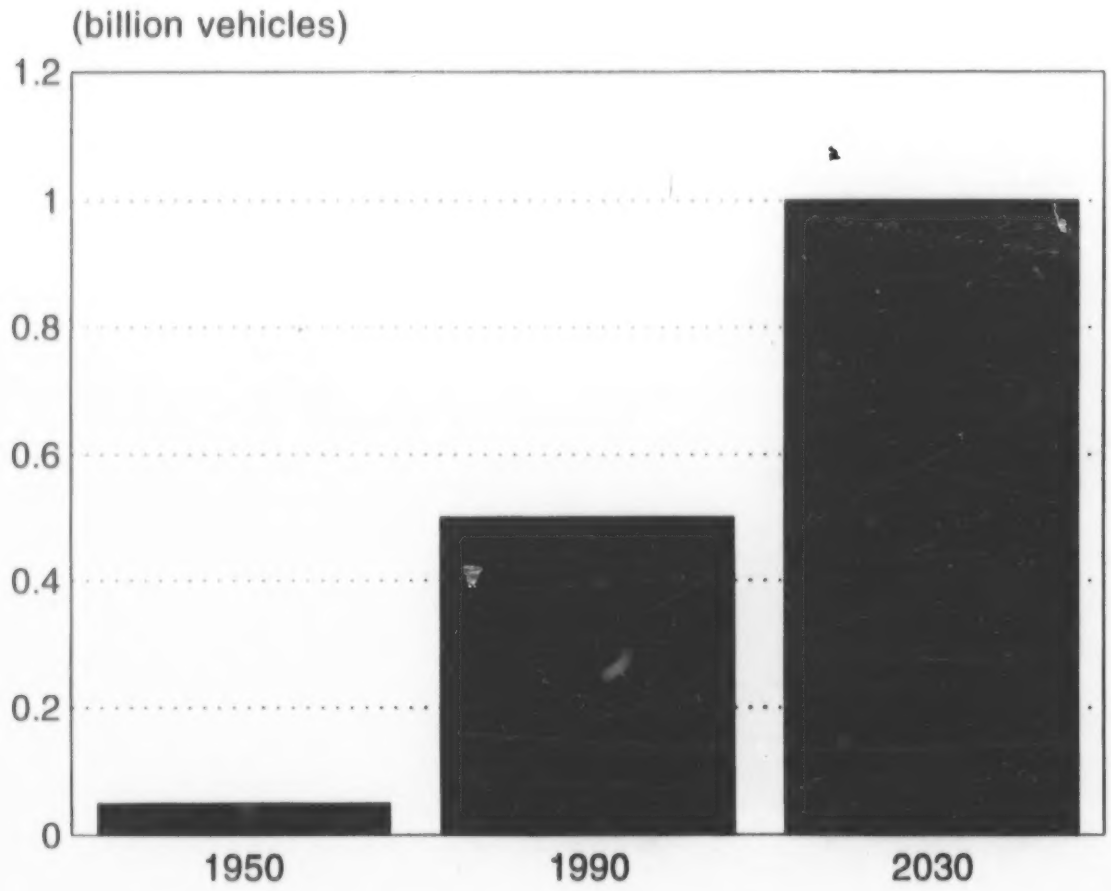
Source: World Resources Institute

Stratospheric Ozone Depletion, 1979–91



Source: World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP), "Scientific Assessment of Stratospheric Ozone, 1991," executive summary (WMO, October 22, 1991), pp. 2 and 4.

Number of Vehicles in the World



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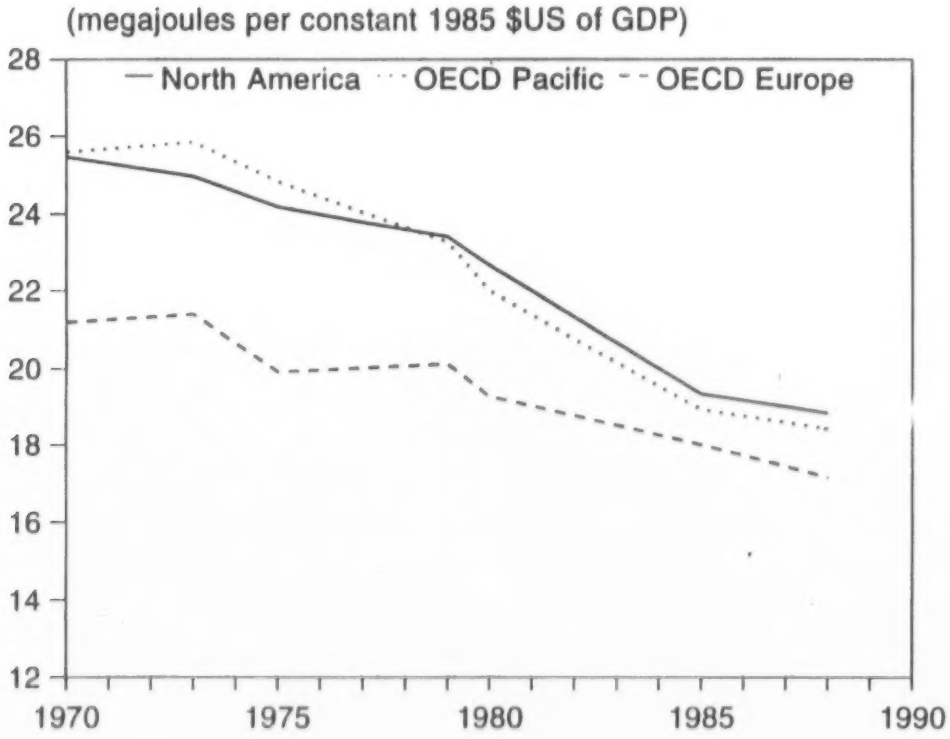
Source: World Resources Institute in collaboration with the United Nations Environment Programme and the United Nations Development Programme, *World Resources 1992–93* (Oxford University Press, New York, 1992), compiled from data discussed in "Reducing Vehicle Pollution," p. 203.

gy Intensities in Developed Countries



Source: Organisation for Economic Co-operation and Development (OECD), *The State of the Environment* (OECD, Paris, 1991), p. 226.
Notes: *North America* here refers to Canada and the United States; *OECD Pacific* refers to Japan, Australia, and New Zealand; *OECD Europe* refers to Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, and the United Kingdom. *GDP* = gross domestic product. GDP is the final output of goods and services produced by the domestic economy, including net exports of goods and nonfactor services. Most countries estimate GDP by adding the final outputs of the various sectors of the economy (agriculture, manufacturing, government services, etc.) after subtracting the inputs to production. *One megajoule* = 10^6 joules.

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Teacher's Survey
Teacher's Guide Units

(Please use additional paper if necessary)

1. Which *World Resources Teacher's Guide* unit did you use?

___1. Biodiversity
___2. Car Trouble
___3. Citizen Action
___4. Energy, Atmosphere, and Climate
___5. Natural Resource Economics
___6. Oceans and Coasts
___7. Population, Poverty, and Land Degradation
___8. Sustainable Development
___9. Two Giants: China and India
___10. Watershed Pollution
___11. Women, Equity, and Sustainable Development

2. Course(s) in which you used *World Resources Teacher's Guide* units?

___History ___Geography ___Science
___Ecology ___Biology ___Chemistry
___Environmental Studies ___Environmental Science ___Other

3. Which sections of the unit did you find most useful?

___Teaching Strategies
___Student Enrichment Activities
___Student Handouts
___Overhead Transparency Masters
___Reading and AV Lists

4. How much do you think you will use the *World Resources Teacher's Guide* units in the future?

___Often ___Occasionally ___Rarely

5. Did you use the Goals 2000 draft national performance standards to select material from the units?

___Yes ___No

6. If yes to the above question, which performance standards did you teach?_____

_____

7. Were the recommended activities in the unit useful in teaching those standards?

___Yes ___No

8. What features could be added to the *Teacher's Guide* to make it more useful to you?

_____

_____

_____

9. In what setting did you use the *Teacher's Guide* units?

___Middle school ___12th grade ___Nature center
___High School ___Community college ___Zoo
___10th grade ___College or university ___Museum
___11th grade ___Adult education ___Other

10. Was the material appropriate for your audience?

____Yes No, because_____

11. If you used the unit in a school, how much class time did you and your students spend on it?

____Less than 1 class ____2–3 classes ____1–2 weeks

____1 class ____4–5 classes ____More than 2 weeks

12. Do you regularly teach about global environmental issues?

____Yes ____No

13. If you don't regularly teach global environmental issues, did you find this unit offered enough information and materials to construct your lesson?

____Yes No, I also needed_____

14. Did you use other WRI materials with this unit?

____Yes ____No

If yes, which ones_____

15. Because new units of the *Teacher's Guide* are being developed, it is helpful for us to learn how the materials work. Did they engage your students? Prompt lively discussion? Help make what seemed abstract issues vivid? Please be specific with negative *or* positive comments.

_____

_____

_____

_____

Name_____

School or Organization_____

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May we call you to discuss your suggestions?

____No Yes, I can be reached at_____

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Sustainable Development Unit / 34 pages
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